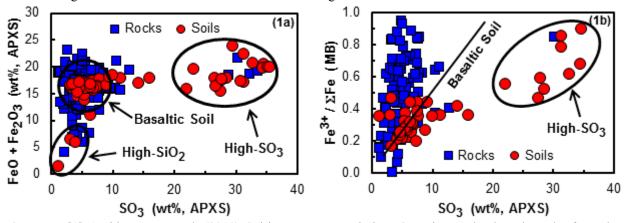
Acid Sulfate Alteration in Gusev Crater, Mars

¹Morris, R. V., ¹Ming, D. W., and ²Catalano, J. G. ¹NASA Johnson Space Center, Houston, TX, 77058, USA ²Washington University in St. Louis, St. Louis, MO, 63130, USA

The Mars Exploration Rover (MER) *Spirit* landed on the Gusev Crater plains west of the Columbia Hills in January, 2004, during the martian summer (sol 0; sol = 1 martian day = 24 hr 40 min). Spirit explored the Columbia Hills of Gusev Crater in the vicinity of Home Plate at the onset on its second winter (sol ~900) until the onset of its fourth winter (sol ~2170) At that time, *Spirit* became mired in a deposit of fined-grained and sulfate-rich soil with dust-covered solar panels and unfavorable pointing of the solar arrays toward the sun. *Spirit* has not communicated with the Earth since sol 2210 (January, 2011) [1]. Like its twin rover *Opportunity*, which landed on the opposite side of Mars at Meridiani Planum, *Spirit* has an Alpha Particle X-Ray Spectrometer (APXS) instrument for chemical analyses and a Mössbauer spectrometer (MB) for measurement of iron redox state, mineralogical speciation, and quantitative distribution among oxidation (Fe³⁺/ Σ Fe) and coordination (octahedral versus tetrahedral) states and mineralogical speciation (e.g., olivine, pyroxene, ilmenite, carbonate, and sulfate) [2].

The concentration of SO_3 in Gusev rocks and soils varies from ~1 to ~34 wt% (Fig. 1a) [3,4,5]. Because the APXS instrument does not detect low atomic number elements (e.g., H and C), major-element oxide concentrations are normalized to sum to 100 wt%, i.e., contributions of H_2O , CO_2 , NO_2 , etc. to the bulk composition care not considered. The majority of Gusev samples have ~ 6 \pm 5 wt% SO_3 , but there is a group of samples with high SO_3 concentrations (~30 wt%) and high total iron concentrations (~20 wt%). There is also a group with low total Fe and SO_3 concentrations that is also characterized by high SiO_2 concentrations (>70 wt%) (Fig. 1a). The trend labeled "Basaltic Soil" is interpreted as mixtures in variable proportions between unaltered igneous material and oxidized and SO_3 -rich basaltic dust. The Mössbauer parameters are not definitive for mineralogical speciation (other than octahedrally-coordinated Fe³⁺ but are consistent with a schwertmannite-like phase (i.e., a nanophase ferric oxide).

The high oxidation state (Fig. 1b) and values of Mössbauer parameters (center shift and quadrupole splitting) for the high-SO₃ samples imply ferric sulfate (i.e., oxidized sulfur), although the hydration state cannot be constrained. In no case is there an excess of SO₃ over available cations (i.e., no evidence for elemental sulfur), and Fe sulfide (pyrite) has been detected in only one Gusev sample. The presence of both high-SiO₂ (and low total iron and SO₃) and high SO₃ (and high total iron as ferric sulfate) can be accommodated by a two-step geochemical model developed with the Geochemist's Workbench. (1) Step 1 is anoxic acid sulfate leaching of martian basalt at high water-to rock ratios (>70). The result is a high-SiO₂ residue (Fig 1a), and anoxic conditions are required to solubilize Fe as Fe²⁺. (2) Step 2 is the oxic precipitation of sulfate salts from the leachate. Oxic conditions are required to produce the high concentrations of ferric sulfate with minor Mg-sulfates and no detectable Fe²⁺-sulfates.



References: [1] Arvidson RE, et al. (2010) Spirit Mars rover mission: Overview and selected results from the northern Home Plate winter haven to the side of Scamander crater, *J. Geophys. Res.*, 115, E00F03. [2] Squyres SW, et al. (2003) The Athena Mars rover science investigation, *J. Geophys. Res.*, 108, 8062. [3] Morris RV, et al. (2006) Mössbauer mineralogy of rock, soil, and dust at Gusev Crater, Mars: Spirit's journey through weakly altered olivine basalt on the Plains and pervasively altered basalt in the Columbia Hills, *J. Geophys. Res.*, 111, E02S13. [4] Morris RV, et al. (2008) Iron mineralogy and aqueous alteration from Husband Hill through Home Plate at Gusev Crater, Mars: Results from the Mössbauer instrument on the Spirit Mars Exploration Rover, *J. Geophys. Res.*, 113, E12S42. [5] Morris RV, et al (2016) Mineralogy and geochemistry of sulfate-rich and silica-rich products of acid-sulfate alteration of basalt under high water-to-rock ratios at Home Plate in Gusev Crater, Mars, to be submitted.